Name: ________________________ **Class:** ___________________ **Date:** __________ **ID: A**

Physics 12 - Momentum and Energy

Modified True/False

Indicate whether the statement is true or false. If false, change the identified word or phrase to make the statement true.

____ 1. *More work is done* to lift a 2.00-kg object a distance of 1.00 m at a constant velocity than to push a 1.00-kg block a distance of 1.00 m with a force of 19.6 N. ______________________________

____ 2. The maximum work a force can do on an object occurs when the force is *parallel* to the direction of motion. _________________________

____ 3. To raise a 2.3-kg mass from its resting place on a table, *more work is done* by lifting it diagonally than lifting it straight up. ___________________________________

____ 4. If you raise an object above your head and then set it on a table, *you do the same work* as if you only lifted the object onto the table. ______________________________

____ 5. The change in gravitational potential energy *can never have* a negative value. _________________________

____ 6. A group of three balls at the top of three different frictionless ramps drop the same vertical distance *with the same final speed* regardless of the shape of the ramp. _________________________

____ 7. If the net force acting on a system of objects is zero, the linear momentum of the system is conserved *for any number of objects*. _________________________

____ 8. *Momentum is not conserved* in all collisions. _________________________

____ 9. When you triple the velocity of an object of constant mass, you also *triple the momentum*. _________________________

____ 10. The equation $F_g = mg$ is valid *everywhere.* ______________________________

____ 11. The general equation of gravitational potential energy, $E_g = -\frac{GMm}{r}$, *is not valid* near Earth's surface. _________________________

____ 12. Earth's gravitational force is exerted everywhere, so it would be *impossible* for a space probe launched from Earth to escape from it. _________________________

Multiple Choice

Identify the choice that best completes the statement or answers the question.

____ 13. A child pulls a 7.4-kg toboggan 4.2 m across level ground with a 15-N force that is 34° above the horizontal. The work done is

a. 35 J
b. 52 J
c. 63 J
d. 3.9×10^2 J
e. 2.1×10^3 J

____ 14. A farmhand does 972 J of work pulling an empty hay wagon along level ground with a force of 310 N [23° below the horizontal]. A frictional force of 280 N opposes the motion. The distance the wagon travels is

a. 0.39 m
b. 1.7 m
c. 3.4 m
d. 32 m
e. 1.8×10^2 m

____ 15. A student in a lab exerts a 25 N force to pull a block a distance of 48 cm. If a total of 11 J of work is done, the angle between the force and the displacement is

a. 89°
b. 66°
c. 61°
d. 24°
e. none of the above

____ 16. A 75-kg parachutist jumps from a plane at a height of 1.2 km. At the instant he leaves the plane, his gravitational potential energy compared to the plane is

a. 8.8×10^2 J
b. -8.8×10^3 J
c. 8.8×10^5 J
d. -8.8×10^5 J
e. 0 J

____ 17. A car slows down as it descends a hill. Which of the following is true?

a. the gravitational potential energy decreases
b. the kinetic energy increases
c. heat is produced by friction
d. two of A, B, and C are correct
e. all of A, B, and C are correct

____ 18. A 102-g sparrow flying at 12.3 m/s wishes to have equal kinetic and gravitational potential energies. The height that will accomplish this is

a. 0.315 m
b. 0.628 m
c. 0.787 m
d. 1.13 m
e. 7.72 m

____ 19. A cyclist reaches the bottom of a hill with a speed of 18 m/s. Neglecting air resistance and other friction, to what maximum height can they coast up the hill without pedalling?

a. 17 m
b. 18 m
c. 19 m
d. 20 m
e. 21 m

____ 20. Rubbing your hands together can quickly produce 45 J of thermal energy. If it is done with an average frictional force of 8.4 N, the distance your hands have slid past each other is

a. 49 m
b. 5.4 m
c. 4.5 m
d. 3.7 m
e. 1.2 m

____ 21. A student exerts a force of 12 N to compress a spring 2.54 cm. The force constant for the spring is

a. 0.30 N/m
b. 4.7 N/m
c. 15 N/m
d. 31 N/m
e. 4.7×10^2 N/m

____ 22. A horizontal spring, with a force constant of 39 N/m, is compressed 12.4 cm, and placed between a wall and a 0.17-kg box resting on a smooth floor. If the spring is released, the maximum speed of the box is

a. 1.9 m/s
b. 2.7 m/s
c. 3.5 m/s
d. 5.3 m/s
e. 28 m/s

____ 23. During an experiment carried out by an astronaut on the Moon (g = 1.6 N/kg), a 1.4-kg mass is dropped onto a spring with a force constant of 49 N/m. The maximum compression in the spring is

a. 0.28 m
b. 0.48 m
c. 3.6 m
d. 4.8 m
e. not enough information

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____ 24. If the mass of a car is doubled and its speed is cut in half, then the kinetic energy changes by a factor of
- a. 0.25
- b. 0.5
- c. 1
- d. 2
- e. 4

____ 25. A rocket triples its height but looses half its mass in fuel. The gravitational potential energy of the rocket has changed by a factor of
- a. 0.33
- b. 0.5
- c. 1
- d. 1.5
- e. 3

____ 26. A bird flying at a height of 12 m doubles its speed as it descends to a height of 6.0 m. The kinetic energy has changed by a factor of
- a. 0.25
- b. 0.5
- c. 1
- d. 2
- e. 4

____ 27. A bird flying at a height of 12 m doubles its speed as it descends to a height of 6.0 m. The gravitational potential energy has changed by a factor of
- a. 0.25
- b. 0.5
- c. 1
- d. 2
- e. 4

____ 28. A 5.0-kg cat travelling at 1.3 m/s [E] has a momentum of
- a. 6.5 m/s [E]
- b. 6.5 m/s [W]
- c. 3.8 m/s [E]
- d. 3.8 m/s [W]
- e. none of the above

____ 29. A bullet with a momentum of 2.8 kg·m/s [E] is travelling at a speed of 187 m/s. The mass of the bullet is
- a. 0.015 g
- b. 0.067 g
- c. 15 g
- d. 67 g
- e. not enough information

____ 30. A net force of 12 N changes the momentum of a 250-g ball by 3.7 kg·m/s. The force acts for
- a. 0.31 s
- b. 0.81 s
- c. 1.2 s
- d. 3.2 s
- e. 44 s

____ 31. A car with a mass of 1800 kg slows from 42 km/h [E] to 28 km/h [E]. The impulse from the brakes is
- a. 2.5×10^4 N·s [E]
- b. 2.5×10^4 N·s [W]
- c. 2.1×10^4 N·s [E]
- d. 2.1×10^4 N·s [W]
- e. 7.0×10^3 N·s [W]

____ 32. A moving curling stone, A, collides head on with a stationary stone, B. Both stones are of identical mass. If friction is negligible during this linear elastic collision,
- a. stone A will slow down
- b. after the collision, the momentum of stone B will be less than that of stone A
- c. both stones will come to rest shortly after the collision
- d. after the collision, the kinetic energy of the stone B will be less than that of stone A
- e. after the collision, stone A will have a speed of zero

____ 33. If an arrow's mass is doubled and the speed is halved, the momentum is changed by a factor of
- a. 0.25
- b. 0.5
- c. 1
- d. 2
- e. 4

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____ 34. A sabotaged curling stone explodes into three pieces as it travels across the ice. Neglecting the force of friction,
a. all three pieces will travel at the same speed
b. the magnitudes of the momenta for each piece will be the same
c. an external net force had to act on the stone to accelerate the three pieces
d. the components perpendicular to the original motion must add up to zero
e. momentum is not conserved because of the small explosive charge

____ 35. When you catch a fast-moving baseball, your hand hurts less if you move it in the direction of the ball because
a. the ball changes momentum more slowly
b. the force applied is smaller
c. you decrease the impulse required to stop the ball
d. two of A, B, and C
e. all of A, B, and C

____ 36. The force of gravity between two 4.0-kg objects that are 10.0 cm apart is
a. 1.1×10^{-11} N
b. 1.1×10^{-7} N
c. 1.1×10^{-8} N
d. 2.7×10^{-11} N
e. 2.7×10^{-8} N

____ 37. If the mass of Earth is 5.98×10^{24} kg and the radius is 6.38×10^{6} m, the gravitational potential energy of a 1.2×10^{3}-kg satellite located in an orbit 230 km above the surface of Earth is
a. -1.1×10^{4} J
b. -7.2×10^{10} J
c. -2.1×10^{12} J
d. -9.0×10^{12} J
e. -2.1×10^{15} J

____ 38. If an orbiting satellite has a total energy of -1.4×10^{12} J, then the binding energy is
a. -1.4×10^{12} J
b. $+1.4 \times 10^{12}$ J
c. -2.8×10^{12} J
d. -7.0×10^{11} J
e. not enough information

____ 39. The total energy of a 257-kg satellite in orbit at an altitude of 5.9×10^{6} m above Earth's surface ($r_E = 6.38 \times 10^{6}$ m, $M_E = 5.98 \times 10^{24}$ kg) is
a. -4.2×10^{9} J
b. -1.2×10^{10} J
c. -1.6×10^{10} J
d. -2.7×10^{10} J
e. -5.4×10^{10} J

____ 40. The speed of a satellite in orbit 7.4×10^{6} m from the centre of Earth is
a. 2.0×10^{3} km/h
b. 7.3×10^{3} km/h
c. 2.6×10^{4} km/h
d. 5.4×10^{7} km/h
e. dependent on the mass of the satellite

____ 41. A satellite of mass *m* is in orbit around a planet of mass *M* at an altitude *a* above the planet's surface. The radius of the planet is *r*. The speed of the satellite is
a. $v = \sqrt{\dfrac{GM}{r}}$
b. $v = \sqrt{\dfrac{Gm}{r}}$
c. $v = \sqrt{\dfrac{Gm}{r + a}}$
d. $v = \sqrt{\dfrac{GM}{a}}$
e. $v = \sqrt{\dfrac{GM}{r + a}}$

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Short Answer

42. A 57-g tennis ball travelling at 28 m/s is hit straight back with the same velocity. Determine the average force on the tennis ball if the racket is in contact with the ball for 4.9 ms.

43. A 0.25-kg snowball moving at 15 m/s [E] collides and sticks with a 1.9-kg toy truck travelling at 2.8 m/s [W]. Neglecting friction, calculate the velocity of the snowball–truck system after the collision.

44. A 25-kg bag of cement thrown at 2.5 m/s [E] is caught by a person sliding 1.8 m/s [E] on a frictionless surface. If the velocity after the catch is 2.0 m/s, calculate the mass of the person.

45. Is the equation $F_G = \dfrac{GMm}{r^2}$ valid deep inside Earth?

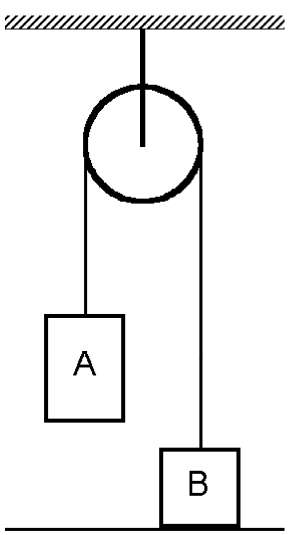
Problem

46. A toy gun fires a 9.41-g projectile disc by using a compressed spring ($k = 1.72 \times 10^3$ N/m) and a 13.1 cm long barrel. As the disc travels through the barrel, it experiences a constant frictional force of 0.13 N. If the spring is compressed 14 mm, what is the speed of the disc as it leaves the gun?

47. A 23-kg block slides 18 m on level ground before coming to rest. If 430 J of work are done by friction, calculate the coefficient of friction between the block and the ground.

48. An 87-g box is attached to a spring with a force constant of 82 N/m. The spring is compressed 11 cm and the system is released.
(a) What is the speed of the box when the spring is stretched by 7.0 cm?
(b) What is the maximum speed of the box?

49. Two boxes are connected over a pulley and held at rest as shown below. Box A has a mass of 15 kg and box B has a mass of 12 kg. If the bottom of box A is originally 85 cm above the floor, with what speed will it contact the floor when the system is released? Use conservation of energy and assume that friction is negligible.



50. A 0.40-kg cue ball makes a glancing blow to a stationary 0.30-kg billiard ball so that the cue ball deflects with a speed of 1.2 m/s at an angle of 30.0º from its original path. Calculate the original speed of the cue ball if the billiard ball ends up travelling at 1.5 m/s.

51. A small explosive charge is placed in a rubber block resting on a smooth surface. When the charge is detonated, the block breaks into three pieces. A 200-g piece travels at 1.4 m/s, and a 300-g piece travels at 0.90 m/s. The third piece flies off at a speed of 1.8 m/s. If the angle between the first two pieces is 80º, calculate the mass and direction of the third piece. Assume two significant digits for each value.

52. During a game of billiards, the 0.30-kg cue ball, travelling at 2.1 m/s, glances off a stationary 0.28-kg billiard ball so that the billiard ball moves off at 1.4 m/s at an angle of 38º from the cue ball's original path. Find the new speed of the cue ball.

53. How much work is done against gravity to fire a 7.2×10^2-kg weather monitor 120 km into the air? ($r_E = 6.38 \times 10^6$ m, $M_E = 5.98 \times 10^{24}$ kg)

54. Uranus orbits the Sun ($M_S = 1.99 \times 10^{30}$ kg) with a mean radius of 2.87×10^{12} m. How long does it take Uranus to complete one orbit? Give your answer in Earth years.

55. A satellite is in orbit around Earth at an altitude of 3700 km. How much must its speed increase, in kilometres per hour, to escape Earth's force of gravity?

56. Mercury has a radius of 2.57×10^6 m and an escape speed of 4.13 km/s. What is the mass of Mercury?

Physics 12 - Momentum and Energy
Answer Section

MODIFIED TRUE/FALSE

1. ANS: F, The same amount of work is done

   PTS: 1 REF: K/U OBJ: 4.1 STA: EM1.01
2. ANS: T PTS: 1 REF: K/U
   OBJ: 4.1 STA: EM1.01
3. ANS: F, the same amount of work is done

   PTS: 1 REF: K/U OBJ: 4.3 STA: EM1.01
4. ANS: T PTS: 1 REF: K/U
   OBJ: 4.3 STA: EM1.01
5. ANS: F, can have

   PTS: 1 REF: K/U OBJ: 4.3 STA: EM1.01
6. ANS: T PTS: 1 REF: K/U
   OBJ: 4.4 STA: EM1.03
7. ANS: T PTS: 1 REF: C
   OBJ: 5.2 STA: EM1.02
8. ANS: T PTS: 1 REF: K/U
   OBJ: 5.2 STA: EM1.03
9. ANS: T PTS: 1 REF: K/U
   OBJ: 5.1 STA: EM1.01
10. ANS: F, near the surface of a planet

    PTS: 1 REF: K/U OBJ: 6.1 STA: EM1.06
11. ANS: F, is valid

    PTS: 1 REF: K/U OBJ: 6.3 STA: EM1.06
12. ANS: F, possible

    PTS: 1 REF: K/U OBJ: 6.3 STA: EM1.07

MULTIPLE CHOICE

13. ANS: B PTS: 1 REF: K/U OBJ: 4.1
    STA: EM1.01
14. ANS: C PTS: 1 REF: K/U OBJ: 4.1
    STA: EM1.01
15. ANS: D PTS: 1 REF: K/U OBJ: 4.1
    STA: EM1.01
16. ANS: E PTS: 1 REF: K/U OBJ: 4.3
    STA: EM1.01

17. ANS: D PTS: 1 REF: K/U OBJ: 4.2 | 4.3
STA: EM1.01
18. ANS: E PTS: 1 REF: K/U OBJ: 4.2 | 4.3
STA: EM1.01
19. ANS: A PTS: 1 REF: K/U OBJ: 4.4
STA: EM1.03
20. ANS: B PTS: 1 REF: MC OBJ: 4.4
STA: EM1.03
21. ANS: E PTS: 1 REF: K/U OBJ: 4.5
STA: EM1.08
22. ANS: A PTS: 1 REF: K/U OBJ: 4.5
STA: EM1.03
23. ANS: E PTS: 1 REF: K/U OBJ: 4.5
STA: EM1.08
24. ANS: B PTS: 1 REF: K/U OBJ: 4.2
STA: EM1.01
25. ANS: D PTS: 1 REF: K/U OBJ: 4.3
STA: EM1.01
26. ANS: E PTS: 1 REF: K/U OBJ: 4.2
STA: EM1.01
27. ANS: B PTS: 1 REF: K/U OBJ: 4.2
STA: EM1.01
28. ANS: E PTS: 1 REF: C OBJ: 5.1
STA: EM1.01
29. ANS: C PTS: 1 REF: K/U OBJ: 5.1
STA: EM1.01
30. ANS: A PTS: 1 REF: K/U OBJ: 5.1
STA: EM1.01
31. ANS: E PTS: 1 REF: K/U OBJ: 5.1
STA: EM1.01
32. ANS: E PTS: 1 REF: MC OBJ: 5.3
STA: EM1.04
33. ANS: C PTS: 1 REF: K/U OBJ: 5.1
STA: EM1.01
34. ANS: D PTS: 1 REF: K/U OBJ: 5.4
STA: EM1.03
35. ANS: D PTS: 1 REF: MC OBJ: 5.1
STA: EM1.01
36. ANS: B PTS: 1 REF: K/U OBJ: 6.1
STA: EM1.06
37. ANS: B PTS: 1 REF: K/U OBJ: 6.3
STA: EM1.07
38. ANS: B PTS: 1 REF: K/U OBJ: 6.3
STA: EM1.07
39. ANS: A PTS: 1 REF: K/U OBJ: 6.3
STA: EM1.07
40. ANS: C PTS: 1 REF: K/U OBJ: 6.2
STA: EM1.07

41. ANS: E PTS: 1 REF: K/U OBJ: 6.3
STA: EM1.07

SHORT ANSWER

42. ANS:
We can neglect the force of gravity because it is so small.

$$\Sigma F_x \Delta t = m(v_{fx} - v_{ix})$$

$$\Sigma F_x = \frac{m(v_{fx} - v_{ix})}{\Delta t}$$

$$= \frac{0.057\text{ kg}(28\text{ m/s} - (-28\text{ m/s}))}{4.9 \times 10^{-3}\text{ s}}$$

$$\Sigma F_x = 6.5 \times 10^2\text{ N}$$

The average force acting on the ball is 6.5×10^2 N.

PTS: 1 REF: K/U OBJ: 5.1 STA: EM1.01

43. ANS:
Choose east as the +*x* direction.

$$m_s v_s + m_t v_t = (m_s + m_t) v_{st}$$

$$v_{st} = \frac{m_s v_s + m_t v_t}{m_s + m_t}$$

$$= \frac{(0.25\text{ kg})(15\text{ m/s}) + (1.9\text{ kg})(-2.8\text{ m/s})}{0.25\text{ kg} + 1.9\text{ kg}}$$

$$v_{st} = -0.73\text{ m/s}$$

The final velocity is 0.73 m/s [W].

PTS: 1 REF: K/U OBJ: 5.2 STA: EM1.02

44. ANS:
Choose east as the $+x$ direction.

$$m_s v_s + m_p v_p = (m_s + m_p) v_{sp}$$

$$m_b v_b + m_p v_p = m_b v_{bp} + m_p v_{bp}$$

$$m_\mathrm{p} v_\mathrm{p} - m_\mathrm{p} v_\mathrm{bp} = m_\mathrm{b} v_\mathrm{bp} - m_\mathrm{b} v_\mathrm{b}$$

$$m_\mathrm{p}(v_\mathrm{p} - v_\mathrm{bp}) = m_\mathrm{b} v_\mathrm{bp} - m_\mathrm{b} v_\mathrm{b}$$

$$m_\mathrm{p} = \frac{m_\mathrm{b}(v_\mathrm{bp} - v_\mathrm{b})}{v_\mathrm{p} - v_\mathrm{bp}}$$

$$= \frac{(25\ \mathrm{kg})(2.0\ \mathrm{m/s} - 2.5\ \mathrm{m/s})}{1.8\ \mathrm{m/s} - 2.0\ \mathrm{m/s}}$$

$$m_\mathrm{p} = 62\ \mathrm{kg}$$

The mass of the person is 62 kg.

PTS: 1 REF: K/U OBJ: 5.2 STA: EM1.02

45. ANS:
No. Inside Earth, some of the mass is above the object and some is below, so the equation is not valid.

PTS: 1 REF: K/U OBJ: 6.1 STA: EM1.06

PROBLEM

46. ANS:
Using conservation of energy

$$E_\mathrm{T1} = E_\mathrm{T2}$$

$$\tfrac{1}{2} kx^2 = \tfrac{1}{2} mv^2 + F\Delta d \cos 0°$$

$$v = \sqrt{\frac{kx^2 - 2F\Delta d \cos 0°}{m}}$$

$$= \sqrt{\frac{(1.72 \times 10^3\ \mathrm{N/m})(0.014\ \mathrm{m})^2 - 2(0.13\ \mathrm{N})(0.131\ \mathrm{m})(1)}{0.0941\ \mathrm{kg}}}$$

$$v = 1.8\ \mathrm{m/s}$$

The speed of the disc is 1.8 m/s.

PTS: 1 REF: K/U OBJ: 4.5 STA: EM1.03

47. ANS:

$$W = F_{\text{f}}\Delta d$$

$$F_{\text{f}} = \frac{W}{\Delta d}$$

$$= \frac{430\ \text{J}}{18\ \text{m}}$$

$$F_{\text{f}} = 23.889\ \text{N}$$

$$\Sigma F_y = 0$$

$$F_{\text{N}} - mg = 0$$

$$F_{\text{N}} = (23\ \text{kg})(9.8\ \text{m/s}^2)$$

$$F_{\text{N}} = 225.4\ \text{N}$$

$$\mu_{\text{K}} = \frac{F_{\text{f}}}{F_{\text{N}}}$$

$$= \frac{23.889\ \text{N}}{225.4\ \text{N}}$$

$$\mu_{\text{K}} = 0.10598$$

The coefficient of friction is 0.11.

PTS: 1 REF: K/U OBJ: 4.1 STA: EM1.01

48. ANS:
(a) The total energy is conserved, so
Noting that all the original energy is elastic potential,

$$E_{\mathrm{T}} = E'_{\mathrm{T}}$$

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}kx'^2 + \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{k}{m}(x^2 - x'^2)}$$

$$= \sqrt{\frac{82\ \mathrm{N/m}}{0.087\ \mathrm{kg}}\left((0.11\ \mathrm{m})^2 - (0.070\ \mathrm{m})^2\right)}$$

$$v = 2.6\ \mathrm{m/s}$$

The speed at a stretch of 7.0 cm is 2.6 m/s.

(b) The total energy is conserved.
All of the original energy is elastic potential, and all of the final energy will be kinetic,

$$E_{\mathrm{T}} = E'_{\mathrm{T}}$$

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{k}{m}x^2}$$

$$= \sqrt{\frac{82\ \mathrm{N/m}}{0.087\ \mathrm{kg}}(0.11\ \mathrm{m})^2}$$

$$v = 3.4\ \mathrm{m/s}$$

The maximum speed is 3.4 m/s.

PTS: 1 REF: K/U OBJ: 4.5 STA: EM1.08

49. ANS:
The total energy of the system will not change.

$$E_T = E'_T$$

$$m_A g \Delta y_A = \tfrac{1}{2} m_A v_A^2 + \tfrac{1}{2} m_B v_B^2 + m_B g \Delta y_B$$

$$v_A = v_B = v \text{ (because they are attached)}$$

$$\tfrac{1}{2} v^2 (m_A + m_B) = m_A g \Delta y_A - m_B g \Delta y_B$$

$$v = \sqrt{\frac{m_A g \Delta y_A - m_B g \Delta y_B}{\tfrac{1}{2}(m_A + m_B)}}$$

$$= \sqrt{\frac{(15\text{ kg})(9.8\text{ m/s}^2)(0.85\text{ m}) - (12\text{ kg})(9.8\text{ m/s}^2)(0.85\text{ m})}{\tfrac{1}{2}(15\text{ kg} + 12\text{ kg})}}$$

$$v = 1.4\text{ m/s}$$

The impact speed of box A will be 1.4 m/s.

PTS: 1 REF: K/U OBJ: 4.4 STA: EM1.03

50. ANS:

We will choose the original direction of motion of the cue ball as the +*x* direction.
Using vector components in the *y*-direction,

$$p_y = p'_y$$

$$0 = m_c v'_{cy} \sin 30° - m_b v'_{by} \sin\theta$$

$$\sin\theta = \frac{m_c v'_{cy} \sin 30°}{m_b v'_{by}}$$

$$\theta = \sin^{-1}\left(\frac{m_c v'_{cy} \sin 30°}{m_b v'_{by}}\right)$$

$$= \sin^{-1}\left(\frac{(0.40\text{ kg})(1.2\text{ m/s})\sin 30°}{(0.30\text{ kg})(1.5\text{ m/s})}\right)$$

$$\theta = 32.23°$$

Using vector components in the *x*-direction:

$$p_x = p'_x$$

$$m_c v_{cx} = m_c v'_{cx} \cos 30° + m_b v'_{bx} \cos\theta$$

$$v_{cx} = \frac{m_c v'_{cx} \cos 30° + m_b v'_{bx} \cos\theta}{m_c}$$

$$= \frac{(0.40\text{ kg})(1.2\text{ m/s})\cos 30° + (0.30\text{ kg})(1.5\text{ m/s})\cos 32.23°}{0.40\text{ kg}}$$

$$v_{cx} = 2.0\text{ m/s}$$

The initial speed of the cue ball was 2.0 m/s.

PTS: 1 REF: K/U OBJ: 5.4 STA: EM1.03

51. ANS:
The momentum of the 200-g piece, p_2, is 0.20 × 1.4 = 0.28 kg·m/s.
The momentum of the 300-g piece, p_3, is 0.30 × 0.90 = 0.27 kg·m/s.
The momentum of the unknown piece, p_m, is m × 1.8 = 1.8m kg·m/s.

Choose the +x direction to be the direction of the 200-g piece.
θ is the angle between the unknown momentum vector and opposite to the 200-g momentum vector.

$$p_y = p'_y$$

$$0 = p_3 \sin 80° - p_{\mathrm{m}} \sin \theta$$

$$0 = 0.27 \sin 80° - 1.8 m \sin \theta$$

$$m \sin \theta = 0.1477 \text{ (Equation 1)}$$

$$p_x = p'_x$$

$$0 = p_2 + p_3 \cos 80° - p_{\mathrm{m}} \cos \theta$$

$$0 = 0.28 + 0.27 \cos 80° - 1.8 m \cos \theta$$

$$m \cos \theta = 0.1816 \text{ (Equation 2)}$$

Now divide Equation 1 by Equation 2:

$$\frac{m \sin \theta}{m \cos \theta} = \frac{0.1477}{0.1816}$$

$$\tan \theta = 0.8133$$

$$\theta = 39°$$

Substitute this value into Equation 1:

$$m \sin 39.1° = 0.1477$$

$$m = 0.23 \text{ kg}$$

The angle measured from the 200-g piece is 180º – 39º = 141º.
The mass of the third piece is 0.23 kg and it is moving 141º from the 200-g piece. (It is 139º from the 300-g piece.)

PTS: 1 REF: K/U OBJ: 5.4 STA: EM1.03

52. ANS:

The initial momentum of the cue ball, p_c, is 0.30 × 2.1 = 0.63 kg·m/s.
The final momentum of the billiard ball, p_b, is 0.28 × 1.4 = 0.392 kg·m/s.
The final momentum of the cue ball, p'_c, is 0.30 × v'_c = 0.30v'_c kg·m/s.

Choose the +x direction to be the original direction of the cue ball.
θ is the angle between the original direction of the cue ball and its new direction.

$$p_y = p'_y$$
$$0 = p'_c \sin\theta - p'_b \sin 38°$$
$$0 = 0.30v \sin\theta - 0.392 \sin 38°$$
$$v \sin\theta = 0.8045 \text{ (Equation 1)}$$

$$p_x = p'_x$$
$$p_c = p'_c \cos\theta + p'_b \cos 38°$$
$$0.63 = 0.30v \cos\theta + 0.392 \cos 38°$$
$$v \cos\theta = 1.070 \text{ (Equation 2)}$$

Now divide Equation 1 by Equation 2:

$$\frac{v \sin\theta}{v \cos\theta} = \frac{0.8045}{1.070}$$
$$\tan\theta = 0.7516$$
$$\theta = 37°$$

Substitute this value into Equation 1:

$$v \sin 36.9° = 0.8045$$
$$v = 1.3 \text{ m/s}$$

The new speed of the cue ball is 1.3 m/s.

PTS: 1 REF: K/U OBJ: 5.4 STA: EM1.03

53. ANS:

$W = \Delta E_g$ **The work**

$$= -\frac{GMm}{r_2} - \left(-\frac{GMm}{r_1}\right)$$

$$= GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= (6.67 \times 10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})(720\,\text{kg})\left(\frac{1}{6.38 \times 10^6\ \text{m}} - \frac{1}{6.38 \times 10^6\ \text{m} + 120 \times 10^3\ \text{m}}\right)$$

$W = 8.3 \times 10^8$ J

done against gravity is 8.3 × 10^8 J.

PTS: 1 REF: K/U OBJ: 6.3 STA: EM1.07

54. ANS:

Calculate the speed of travel:

$$v = \sqrt{\frac{GM}{r}}$$

$$= \sqrt{\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.99 \times 10^{30}\ \text{kg})}{2.87 \times 10^{12}\ \text{m}}}$$

$$v = 6801.9\ \text{m/s}$$

Calculate the total distance:

$$C = 2\pi r$$

$$= 2\pi(2.87 \times 10^{12}\ \text{m})$$

$$C = 1.8032 \times 10^{13}\ \text{m}$$

Calculate the time:

$$t = \frac{d}{v}$$

$$= \frac{1.8032 \times 10^{13}\ \text{m}}{6801.9\ \text{m/s}}$$

$$t = 2.6511 \times 10^{9}\ \text{s}$$

Convert to years:

$$2.6511 \times 10^{9}\ \text{s} \times \frac{1\ \text{hr}}{3600\ \text{s}} \times \frac{\text{day}}{24\ \text{hr}} \times \frac{1\ \text{a}}{365.26\ \text{day}} = 84.0\ \text{a}$$

Uranus takes 84.0 Earth years to complete one orbit.

PTS: 1 REF: K/U OBJ: 6.2 STA: EM1.06

55. ANS:
First calculate the speed satellite in orbit:

$$E_T = E_K + E_g$$

$$\tfrac{1}{2}E_g = E_K + E_g$$

$$E_K = -\tfrac{1}{2}E_g$$

$$\tfrac{1}{2}mv^2 = -\tfrac{1}{2}\left(-\frac{GM_E m}{r_O}\right)$$

$$v = \sqrt{\frac{GM_E}{r_O}}$$

$$= \sqrt{\frac{(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98\times10^{24}\ \text{kg})}{6.38\times10^6\ \text{m} + 3700\times10^3\ \text{m}}}$$

$$v = 6290\ \text{m/s}$$

Additional energy required to bring the object to a total energy of zero:

$$E'_K + E_g = 0$$

$$E'_K = -E_g$$

$$= -\left(-\frac{GM_E m}{r_O}\right)$$

$$E'_K = \frac{GM_E m}{r_O}$$

$$\tfrac{1}{2}mv'^2 = \frac{GM_E m}{r_O}$$

$$v' = \sqrt{\frac{2GM_E}{r_O}}$$

$$= \sqrt{2}\sqrt{\frac{GM_E}{r_O}}$$

$$= \sqrt{2}\,v$$

$$= \sqrt{2}\,(6290\ \text{m/s})$$

$$v' = 8896\ \text{m/s}$$

8896 – 6292 = 2604 m/s, or 9.4×10^3 km/h.
The satellite must speed up 9.4×10^3 km/h to leave Earth’s gravity.

PTS: 1 REF: K/U OBJ: 6.3 STA: EM1.07

56. ANS:

$$E_{\text{T}} = 0$$

$$E_{\text{K}} + E_{\text{g}} = 0$$

$$\tfrac{1}{2} mv^2 = -\left(-\frac{GMm}{r_{\text{M}}}\right)$$

$$M = \frac{r_{\text{M}} v^2}{2G}$$

$$= \frac{(2.57 \times 10^6\ \text{m})(4.13 \times 10^3\ \text{m/s})^2}{2(6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2)}$$

$$M = 3.29 \times 10^{23}\ \text{kg}$$

Mercury has a mass of 3.29 × 10^{23} kg.

PTS: 1 REF: K/U OBJ: 6.3 STA: EM1.07